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PINNIPED AND CETACEAN MORTALITY IN CALIFORNIA GILLNET FISHERIES: PRELIMINARY ESTIMATES FOR APRIL 1 TO JUNE 30, 1992

By

Fred Julian

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Pinniped and Cetacean Mortality in California Gillnet Fisheries: Preliminary Estimates for April 1 to June 30, 1992.

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Abstract

The number of marine mammals killed in California gillnet fisheries is estimated for the time period April 1 to June 30, 1992, based on observations made by biological technicians placed aboard commercial fishing vessels. Currently, the number of fishing days is the only available measure of effort for the set and drift net fisheries; therefore, these effort-days are used to extrapolate from observed mortality to total estimated mortality. Extrapolation is done using mean-per-unit and ratio estimators. The coverage rates were 11% and 31% for the set-net and drift-net fisheries, respectively.

For the second quarter of 1992, the estimated mortalities of marine mammals (standard errors in parentheses) for the set-net fisheries are: 1573 (142) California sea lions, 52 (70) harbor seals, and 36 (15) northern elephant seals. No other species were observed killed in the set-net fishery. The estimated mortalities for the drift-net fisheries are: 7 (3) northern elephant seals, 16 (8) common dolphins, 3 (2) Steller sea lions, and 3 (2) Dall's porpoise. During this time period no other species of marine mammals were observed killed in the drift-net fishery. These estimates are based on the assumption that the fishing effort is known without error.

1. Introduction

During the late 1970's and early 1980's, there was a rapid expansion in the use of entangling nets (drift gillnet, set gillnet, multi-panel, and trammel nets) in coastal California waters (Herrick and Hanan, 1988). The incidental kill of many non-target species, including marine mammals, with these nets has became a focus of concern for state and national environmental and legislative bodies. Such was the concern, in fact, that the state of California passed a referendum banning the use of set gillnets in coastal waters of Southern California beginning in 1994.

This report is the first of the quarterly marine mammal mortality estimates for the California gillnet fisheries. The period covered is April 1 to June 30, 1992. Because the primary objective of this report is to succinctly present estimates of marine mammal mortality, the description of the calculations used to arrive at the figures presented herein is less detailed than that in the annual marine mammal mortality reports (e.g. Perkins, et al. 1992). More detailed information regarding calculations and related topics, e.g. fishing effort, can be found in that report.

In this report, pinniped and cetacean mortality is estimated for the second quarter of the calendar year 1992 for two gillnet fisheries: the California halibut/Pacific angel shark set-net fishery and the shark/swordfish drift-net fishery. These mortality estimates are made using mean-per-unit and ratio estimators assuming the fishing effort is known without error. In fact, by nature of its determination, fishing effort is probably biased low, i.e. underestimated. For a description of the two fisheries under consideration and a discussion of their relation to the U. S. Marine Mammal Protection Act (MMPA), see Barlow, et al. (in press) and Lennert, Kruse, and Beeson (1991).

There are four sections of this report. The second and third section discuss the data, calculations, and results for the set-net and drift-net fisheries, respectively. The last section is a brief discussion of the results of these quarterly estimates as they relate to previous mortality estimates.

2. Set-Net Fisheries

Data

Figure 1 shows the frequency distributions for the number of set-net net pulls by area and month, observation type, depth, net length, soak time, and catch (halibut and angel shark). Figure 2 shows the geographic distribution of marine mammal kills for the set-net fisheries. Of the 698 observed net pulls, there were 518 with no marine mammal entanglements. Of the 250 observed entanglements, 180 were sea lions (174 known to be California sea lions, 6 were unidentified), 61 were harbor seals, 5 were northern elephant seals, and 4 were unidentified pinnipeds. No harbor porpoise were reported entangled. There were 130 observed net pulls with sea lion entanglement and 56 with harbor seal entanglement. Table 1 summarizes the total and mean number of entanglements (per net pull) by month and area for each of these four species. The unidentified sea lions were assumed to be California sea lions because no other sea lion species were observed entangled.

Methods

In order to extrapolate from observed marine mammal kill to total kill, the total fishing effort must be estimated. The California Department of Fish and Game (CDFG) provides the National Marine Fisheries Service (NMFS) with quarterly and yearly estimates of fishing effort for both the halibut/angel shark set-net fishery and the shark/swordfish drift-net fishery (Beeson, 1992). For the purpose of estimating total marine mammal kill, the total effort estimates were treated as known, even though they contain some small error due to incomplete and/or inaccurate reporting by fishers.

Results of the exploratory data analyses of Perkins, et al. (1992) show that calendar quarter and geographic stratification contribute significantly to explaining the variability in the observed number of marine mammal entanglements. The current method for estimating quarterly mortality and mortality rates involves stratifying the data into four areas: southern California, Ventura, Channel Islands, and central California. Observed effort for the Channel Islands and central California was very low during the second quarter of 1992. Consequently, reliable mortality rates could not be established for these areas. Instead, the mortality rates (and their corresponding standard errors) for these areas were assumed to be equal to the mortality rates for the Ventura area. This assumption provides a reasonable approximation to actual rates. Variance estimates have been calculated using an analytic variance estimator based on the delta method (Rice, 1988 or Cochran, 1977).

Although net pulls were the sampling unit for observer data, the total fishing effort reported by CDFG was in terms of effort-days; for one vessel, one day of fishing equals one effort-day. Thus total mortality was estimated based on days as the unit of sampling. In the set-net fishery, boats make trips of one to several days duration. Observed trips longer than one day are rare because accommodations for observers are almost nonexistent. During each day of effort a boat makes several net pulls; the mean for this quarter was 3.144 (s.e. = 1.250). Sampling for observation consists of first selecting a boat and then observing all net pulls made during a particular trip. Because all observed set-net trips during this quarter lasted a single day, the observations were treated as a random sample of days.

This report includes estimates of mortality due to the set-net fisheries for the species of marine mammals for which mortality was observed: California sea lions, harbor seals, northern elephant seals, and harbor porpoises. For each species, a kill rate r_s, and total set-net mortality, m_s, is estimated for each area using a mean-per-unit (MPU) estimator with days as the sampling unit. (A ratio estimator based on net pulls cannot be used because even though the observed number of net pulls is known, the total number

of net pulls is unknown.) The MPU estimators and their estimated variances for the southern California and Ventura areas are (see Rice, 1988 or Cochran, 1977):

$$\hat{r}_s = (\Sigma_i\ k_{i,s})/d_s \qquad \hat{\sigma}^2_{r,s} = (1-d_s/D_s)\,(1/d_s)\,\hat{\sigma}^2_{k,s}$$

$$\hat{m}_s = D_s\hat{r}_s \qquad \hat{\sigma}^2_{m,s} = D_s^2\ \hat{\sigma}^2_{r,s}$$

where $k_{i,s}$ is the observed kill per day, $\hat{\sigma}^2_{k,s}$ is the sampling variance of $k_{i,s}$, and d_s and D_s are the observed and total number of days of effort in the stratum, respectively. The indices i and s refer to the day and strata, respectively. The kill rates and variances for the Channel Islands and central California areas were approximated by the rate and variance for the Ventura area. The estimates of overall kill rate, $\hat{r}$, and total mortality, $\hat{m}$, across all strata, and their variances, are then weighted averages:

$$\hat{r} = (\Sigma_s\ D_s\hat{r}_s)/D \qquad \hat{\sigma}^2_r = (\Sigma_s\ D_s^2\ \hat{\sigma}^2_{r,s})/D^2$$

$$\hat{m} = D\hat{r} \qquad \hat{\sigma}^2_m = D^2\hat{\sigma}^2_r$$

where D is the total number of days of effort.

Set-Net Results

Table 2 summarizes the estimated kill rates, $\hat{r}_s$, and kill, $\hat{m}_s$, for each stratum, as well as combined total estimates, $\hat{r}$ and $\hat{m}$, for the four species considered. The estimate for the California sea lion mortality is based on kill data that include 6 unidentified sea lions. These six were assumed to be California sea lions because there were no Steller sea lions observed killed in the set-net fishery during this quarter.

3. Drift-Net Fisheries

Data

Figure 3 shows the frequency distribution for the number of drift-net net pulls by area and month, observation type, depth, net length, and soak time. There were no observations made in the Channel Islands or Central/Northern California areas. Histograms of the swordfish and shark catch are also shown. Figure 4 shows the geographic distribution of marine mammals killed in the drift-net fishery during this quarter of 1992. Of the 30 observed net pulls, there were 23 with no entanglements. Of the 9 entanglements, 5 were common dolphins, 2 were northern elephant seals, 1 was a Steller sea lion, and 1 was a Dall's porpoise. Table 3 summarizes the total and mean number of entanglements (per net pull) for these species stratified by month.

Methods

For the drift-net fishery, boats make a single net pull per day, thus days and net pulls are equivalent units. However, the assumption that observed days are a random sample is not realistic since a trip consists of a cluster of days. Drift-net sampling consists of first selecting a boat and then observing all net pulls made during a multi-day trip. Thus, a mean-per-unit estimator based on days is inappropriate. Instead, the trips were treated as a random sample and mortality rate and total drift-net mortality were estimated using a ratio estimator with trips as the sampling unit and days per trip as the auxiliary variable. Data were not stratified by area because results from Perkins, 1992, indicate that geographic area is not a significant predictor of mortality.

Mortality due to the drift-net fishery was calculated for all species for which kill was actually observed in the period April 1 to June 30, 1992. The estimates of kill rate, $\hat{r}$, and total mortality, $\hat{m}$, and their variances are (see Cochran, 1977 or Rice, 1988):

$$\hat{r} = (\Sigma_i\ k_i)/(\Sigma_i\ d_i), \quad \hat{\sigma}_r^2 = (1-d/D)(1/n)(1/d_{avg}^2)(\hat{r}^2\ \hat{\sigma}_d^2 + \hat{\sigma}_k^2 - 2\hat{r}\hat{\sigma}_{dk})$$

$$\hat{m} = D\hat{r}, \qquad \hat{\sigma}_m^2 = D^2\hat{\sigma}_r^2$$

where k_i and d_i are the observed kill and number of days for the ith trip; d_{avg} is the sample mean number of days per trip; $\hat{\sigma}_d^2$, $\hat{\sigma}_k^2$, and $\hat{\sigma}_{dk}$ are the sampling variances and covariance of d_i and k_i; d is the observed number of days, n is the observed number of trips, and D is the total number of days of effort. In these calculations the finite population correction (1-n/N), where N is the total number of trips was approximated using (1-d/D), because the total number of drift-net trips is not known.

Drift-Net Results

Table 4 summarizes the estimated kill rate, $\hat{r}$, and mortality, $\hat{m}$, for all species for which kill was actually observed.

4. Discussion

Total and observed fishing effort for the four areas of interest, both set and drift net, are shown in Figures 5 and 6. Drift and set-net fishing effort in the Channel Islands and central California areas have been substantially undersampled during this quarter. The Channel Island waters typically contain the highest density of marine mammals and undersampling may bias mortality estimates significantly. Undersampling and biased sampling should be addressed in future observation efforts. Comparing the fishing efforts for this quarter with those in Perkins, et al. (1992)

indicates that the total set-net fishing effort in the Ventura area is substantially below the 1991 level of effort for the same quarter (675 vs. 1083 effort-days). For the set-net fishery the observed average catch of halibut and angel shark per net pull, Figure 1, has not changed much from 1991 levels. The same appears to be true of the average shark catch per net pull in the drift-net fishery, Figure 3. In the drift-net fishery, the observed average number of swordfish caught per net pull is below the 1991 level (0.1 vs. 2.79). While there has been little change in catch when compared to the 1991 average level, marine mammal mortality has changed substantially. In the set-net fishery the kill rate for California sea lions is about three times the kill rate in 1991. The same is true for harbor seals. Using a t-test, these rates represent a significant increase at the α=0.01 level. The kill rate for northern elephant seals in this quarter is twice the kill rate for northern elephant seals in 1991. The drift-net fishery has seen a significant increase at the α=0.01 level in the mortality rate for northern elephant seals and common dolphins from the 1991 levels.

Acknowledgements

Special thanks go to Marilyn Beeson and Doyle Hanan of the California Department of Fish and Game for their work in determining the fishing effort for the gillnet fisheries, and to Al Jackson of NMFS for assistance with observer data. Jay Barlow, Jim Carretta, and Karin Forney kindly reviewed this report and provided valuable input. Finally, we'd like to acknowledge the cooperation of California gillnet fishers who allowed observer access to their boats and to the NOAA observer-technicians and port coordinators who carry out the California gillnet monitoring programs.

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Table 1. Observed pinniped and cetacean entanglements stratified by area, species and month for the set net fisheries. EPNP = entanglements per net pull.

All areas:

Month	Obs. Days	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Unidentified Pinniped		Harbor Porpoise	
			Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	67	225	85	.378	57	.253	20	.0889	1	.00444	2	.00889	0	0
5/92	81	258	129	.500	90	.349	33	.1280	4	.01550	1	.00388	0	0
6/92	74	215	36	.167	27	.126	8	.0372	0	.000	1	.00465	0	0
Total	222	698	250	.385	174	.249	61	.0874	5	.00716	4	.00573	0	0

Southern California, area 1:

Month	Obs. Days	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Unidentified Pinniped		Harbor Porpoise	
			Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	41	123	50	.407	34	.276	13	.1060	1	.00813	2	.01630	0	0
5/92	50	140	78	.557	54	.386	19	.1357	4	.02857	1	.00714	0	0
6/92	53	145	24	.166	16	.110	7	.0483	0	.00000	1	.00690	0	0
Total	144	408	152	.373	104	.255	39	.0966	5	.01225	4	.00980	0	0

Ventura, area 2:

Month	Obs. Days	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Unidentified Pinniped		Harbor Porpoise	
			Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	25	100	34	.340	23	.230	6	.0600	0	0	0	0	0	0
5/92	31	118	51	.432	36	.305	14	.1190	0	0	0	0	0	0
6/92	20	67	12	.179	11	.164	1	.0149	0	0	0	0	0	0
Total	76	285	97	.340	70	.246	21	.0737	0	0	0	0	0	0

Table 1 continued. Observed pinniped and cetacean entanglements stratified by area, species, and month for the set net fisheries. EPNP = entanglements per net pull.

Channel Islands, area 3:

Month	Obs. Days	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Unidentified Pinniped		Harbor Porpoise	
			Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	0	0	0	--	0	--	0	--	0	--	0	--	0	--
5/92	0	0	0	--	0	--	0	--	0	--	0	--	0	--
6/92	1	3	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	3	0	0	0	0	0	0	0	0	0	0	0	0

Central California, area 4:

Month	Obs. Days	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Unidentified Pinniped		Harbor Porpoise	
			Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	1	2	1	.5	0	0	1	.5	0	0	0	0	0	0
5/92	0	0	0	--	0	--	0	--	0	--	0	--	0	--
6/92	0	0	0	--	0	--	0	--	0	--	0	--	0	--
Total	1	2	1	.5	0	0	1	.5	0	0	0	0	0	0

Table 2. Estimated pinniped and cetacean kill rates and total kill, stratified by area and species, in the California halibut/Pacific angel shark set-net fisheries, from April 1 to June 30, 1992. Estimates of total kill are reported to the nearest individual. Estimates of kill rates are reported to 3 significant digits. Estimated standard errors are included in parentheses. KPD = kill per day.

Area		Southern CA		Ventura		Channel Islands		Central CA		Total	
Days of Effort		1045		675		195		17		1932	
California Sea Lion	est. KPD	0.722	(0.113)	0.921	(0.113)	0.921	(0.113)	0.921	(0.113)	0.814	(0.0736)
	est. Kill	755	(118.1)	622	(76.0)	180	(22.0)	16	(1.9)	1573	(142.2)
Harbor Seal	est. KPD	0.271	(0.0469)	0.276	(0.0719)	0.276	(0.0719)	0.276	(0.0719)	0.274	(0.0364)
	est. Kill	283	(49.0)	187	(48.5)	54	(14.0)	5	(1.2)	529	(70.4)
N. Elephant Seal	est. KPD	0.0347	(0.0142)	0.00	(0.00)	0	--	0	--	0.0188	(0.00769)
	est. Kill	36	(14.9)	0	(0.00)	0	--	0	--	36	(14.9)

Table 3. Observed pinniped and cetacean entanglements stratified by species and month for the drift net fishery. This fishery is closed from February through April. EPNP = entanglements per net pull.

Month	Obs. Net Pulls	Total Marine Mammals		California Sea Lion		Harbor Seal		Northern Elephant Seal		Common Dolphin		Dall's Porpoise	
		Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP	Obs. Kill	mean EPNP
4/92	0	0	--	0	--	0	--	0	--	0	--	0	--
5/92	15	4	.267	0	0	0	0	2	.1330	2	.1330	0	0
6/92	15	5	.333	0	0	0	0	0	0	3	.200	1	.0667
Total	30	9	.300	0	0	0	0	2	.0667	5	.167	1	.0333

Table 4. Estimated pinniped and cetacean kill rates and total kill, by species, in the shark/swordfish drift net fishery, from April 1 to June 30, 1992. KPD = kill per day.

Days of Effort	98		
California Sea Lion	est. KPD	0	--
	est. Kill	0	--
Northern Elephant Seal	est. KPD	.0667	(.0313)
	est. Kill	6.53	(3.07)
Common Dolphin	est. KPD	.1667	(.0792)
	est. Kill	16.33	(7.76)
N. Right Whale Dolphin	est. KPD	0	--
	est. Kill	0	--
Pac. White-Sided Dolphin	est. KPD	0	--
	est. Kill	0	--
Steller Sea Lion	est. KPD	.0333	(.0215)
	est. Kill	3.27	(2.10)
Dall's Porpoise	est. KPD	.0333	(.0215)
	est. Kill	3.27	(2.10)

Figure 1. Observed net pull data for entire the halibut/angel shark set-net fishery during the period April 1 to June 30, 1992.

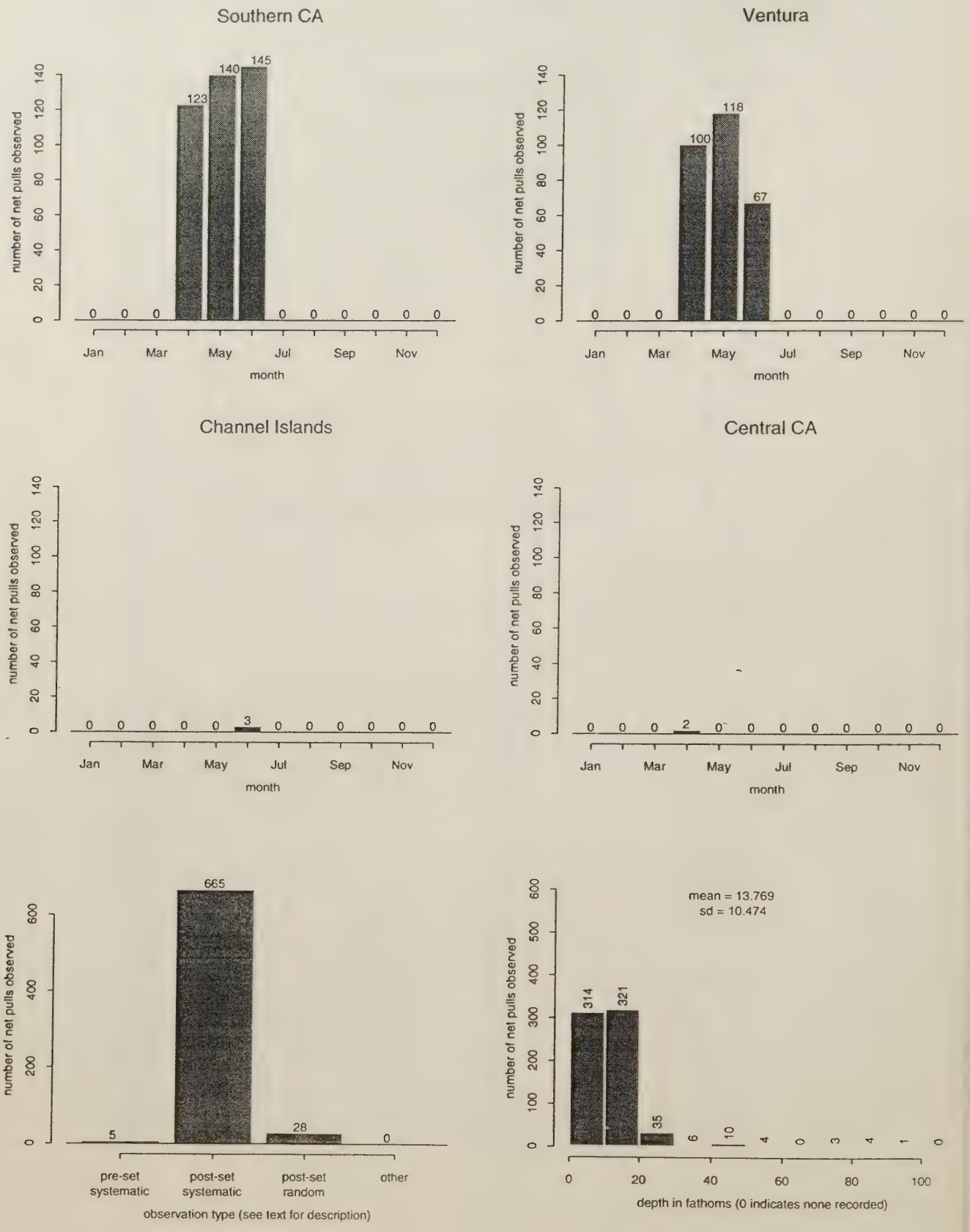
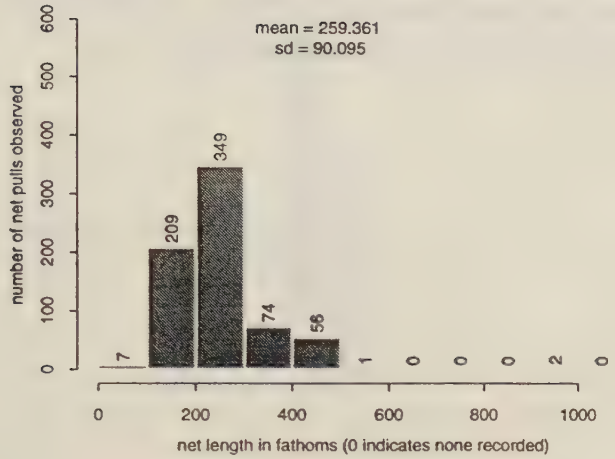
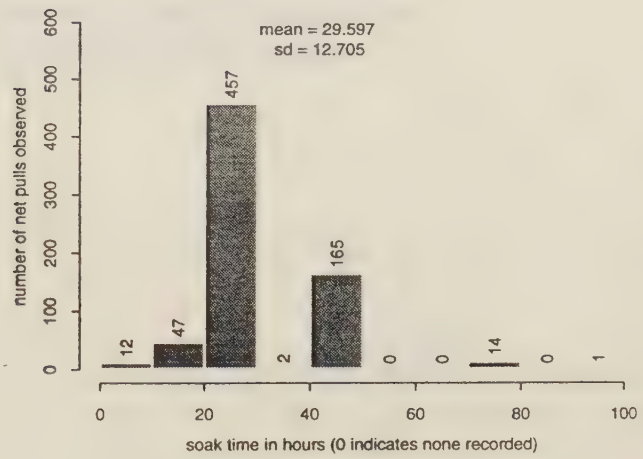
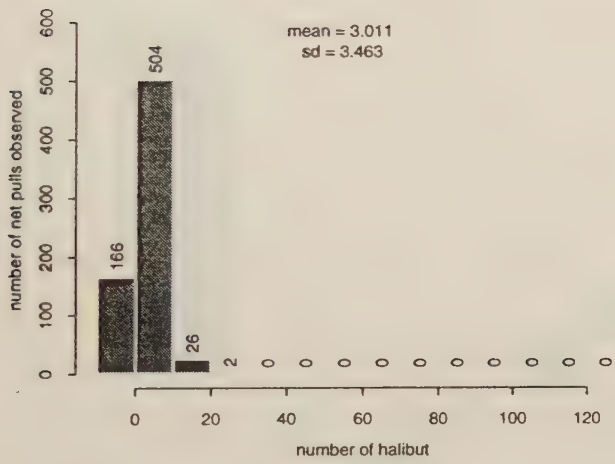

Southern CA
number of net pulls observed
0 20 40 60 80 100 120 140
0 0 0 123 140 145 0 0 0 0 0 0
Jan Mar May Jul Sep Nov
month
Ventura
number of net pulls observed
0 20 40 60 80 100 120 140
0 0 0 100 118 67 0 0 0 0 0 0
Jan Mar May Jul Sep Nov
month
Channel Islands
number of net pulls observed
0 20 40 60 80 100 120 140
0 0 0 0 0 3 0 0 0 0 0 0
Jan Mar May Jul Sep Nov
month
Central CA
number of net pulls observed
0 20 40 60 80 100 120 140
0 0 0 2 0 0 0 0 0 0 0 0
Jan Mar May Jul Sep Nov
month
number of net pulls observed
0 200 400 600
5 665 28 0
pre-set systematic
post-set systematic
post-set random
other
observation type (see text for description)
mean = 13.769
sd = 10.474
number of net pulls observed
0 100 200 300 400 500 600
314 321 35 6 10 4 0 3 4 1 0
0 20 40 60 80 100
depth in fathoms (0 indicates none recorded)

Figure 1. Observed net pull data for the entire halibut/angel shark set-net fishery during the period April 1 to June 30, 1992.







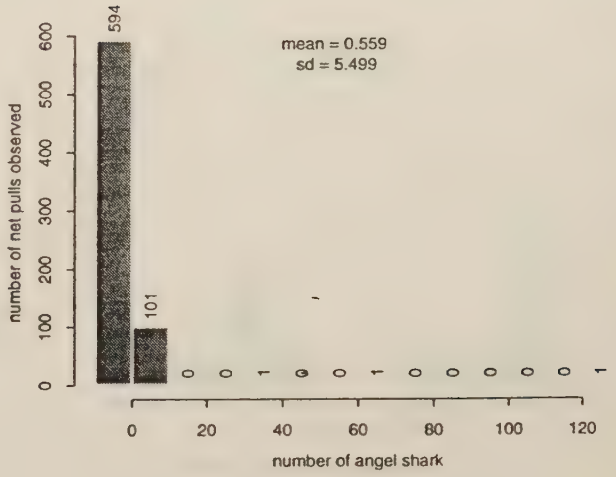


Figure 2. Location of observed marine mammal kills from the halibut/angel shark set-net fishery during the period April 1 to June 30, 1992 - all species. Note: There are no kills indicated in some areas because there was little or no observed effort in those areas, e.g. Channel Islands and central California.

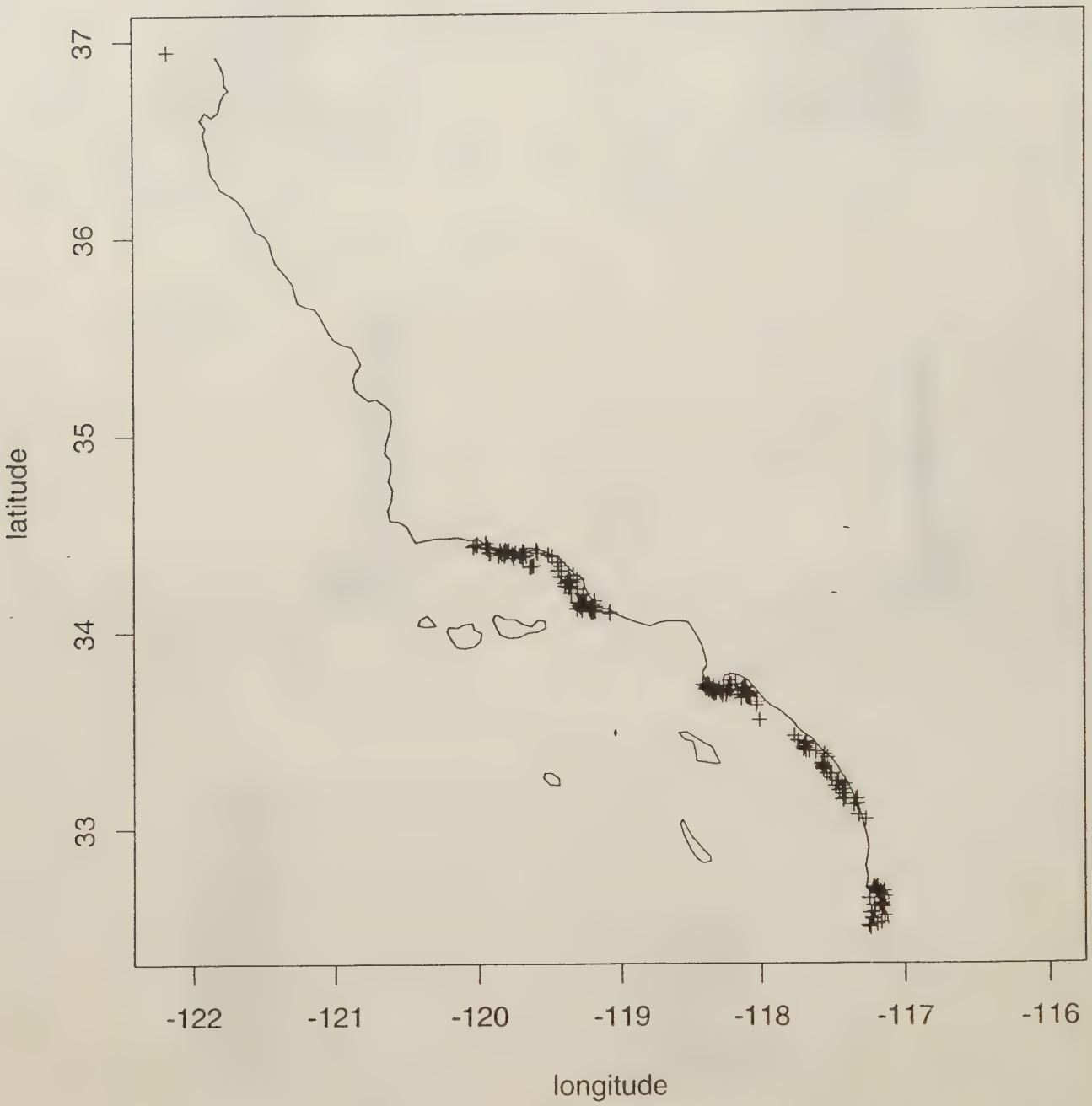
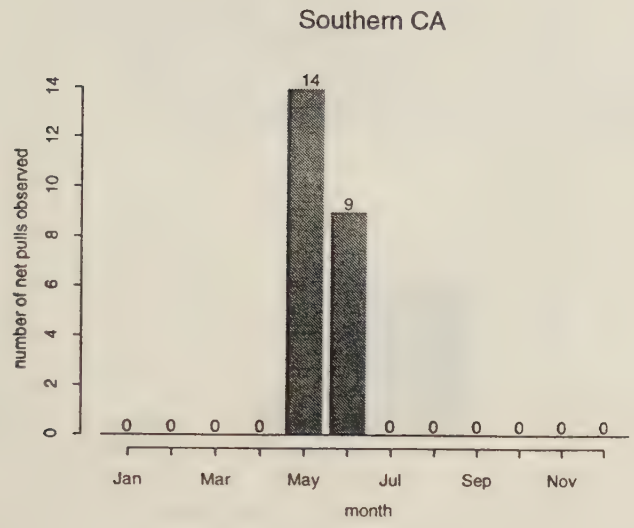
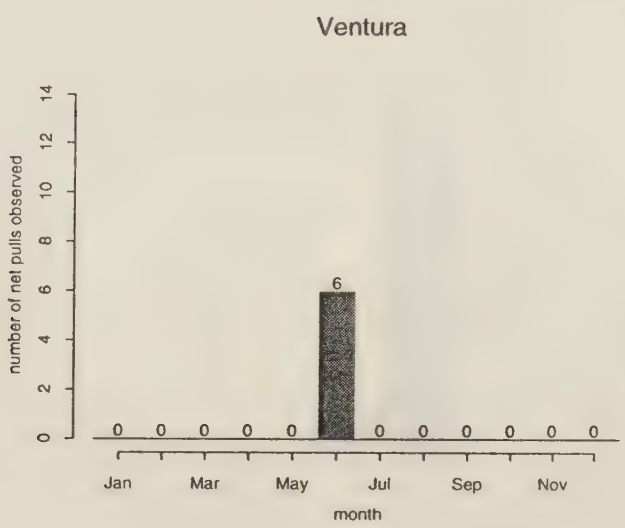
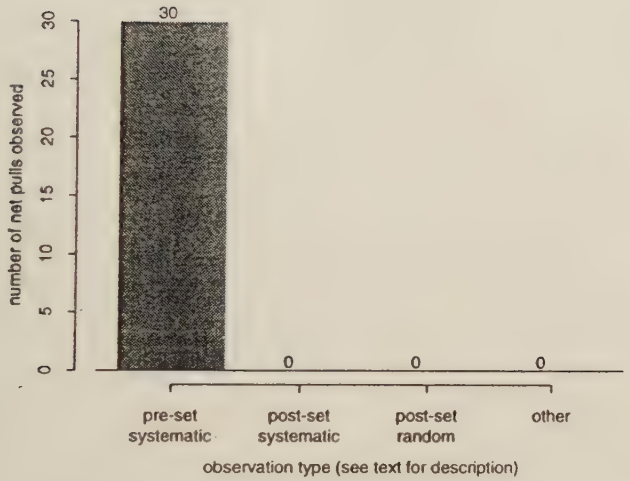
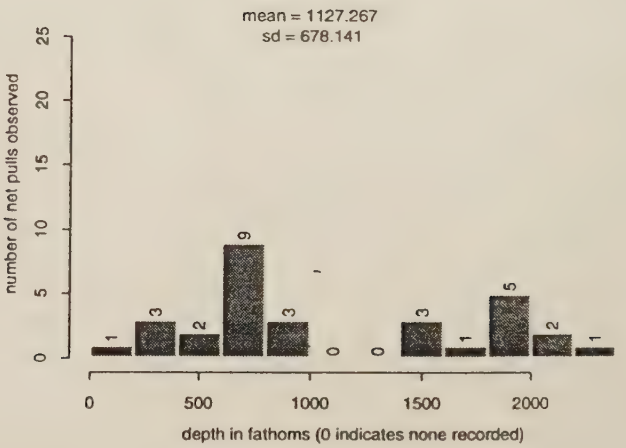


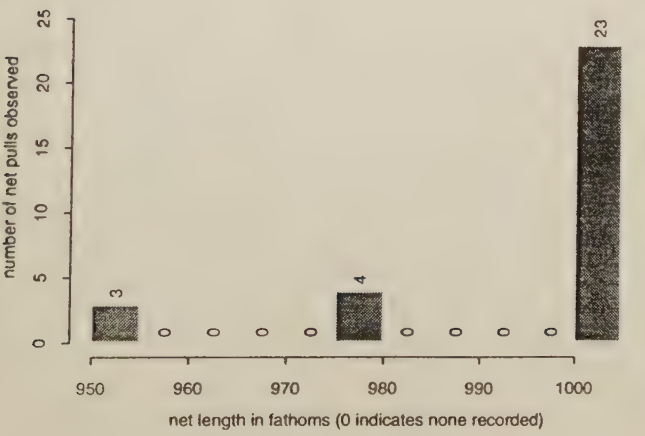
Figure 3. Observed net pull data for the entire shark/swordfish drift-net fishery during the period April 1 to June 30, 1992.








mean = 1127.267
sd = 678.141
number of net pulls observed
0 5 10 15 20 25
1 3 2 9 3 0 0 3 1 5 2 1
0 500 1000 1500 2000
depth in fathoms (0 indicates none recorded)



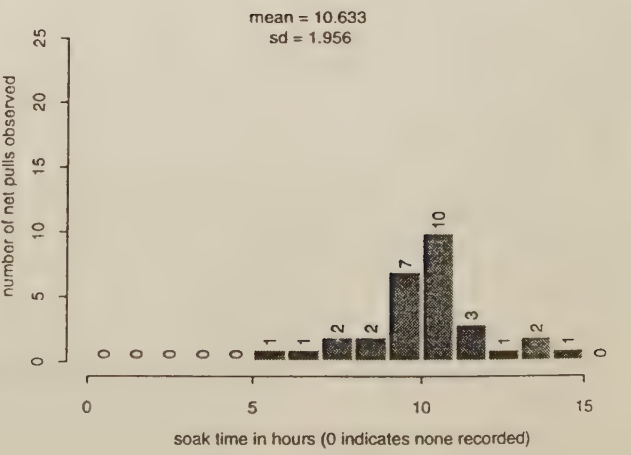
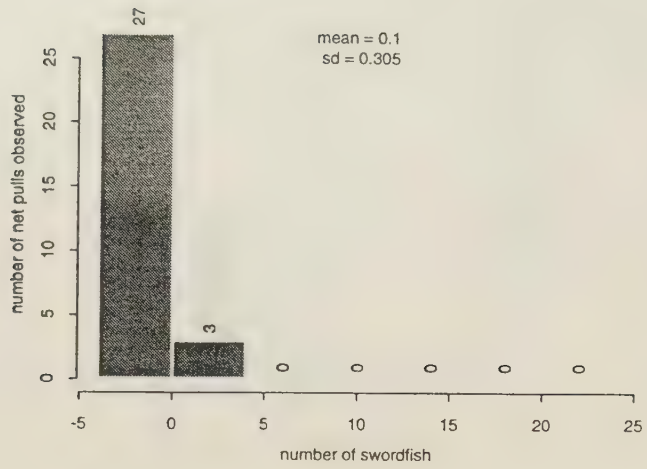

mean = 10.633
sd = 1.956
number of net pulls observed
0 5 10 15 20 25
0 0 0 0 0 1 1 2 2 7 10 3 1 2 1 0
0 5 10 15
soak time in hours (0 indicates none recorded)

Figure 3. Observed net pull data for the entire shark/swordfish drift-net fishery during the period April 1 to June 30, 1992.



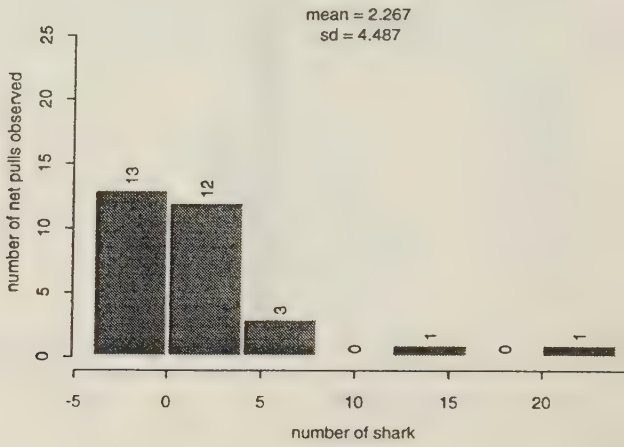


Figure 4. Location of observed marine mammal kills from the shark/swordfish drift-net fishery during the period April 1 to June 30, 1992 - all species. Note: There are no kills indicated in some areas because there was little or no observed effort in those areas, e.g. Channel Islands and central California.

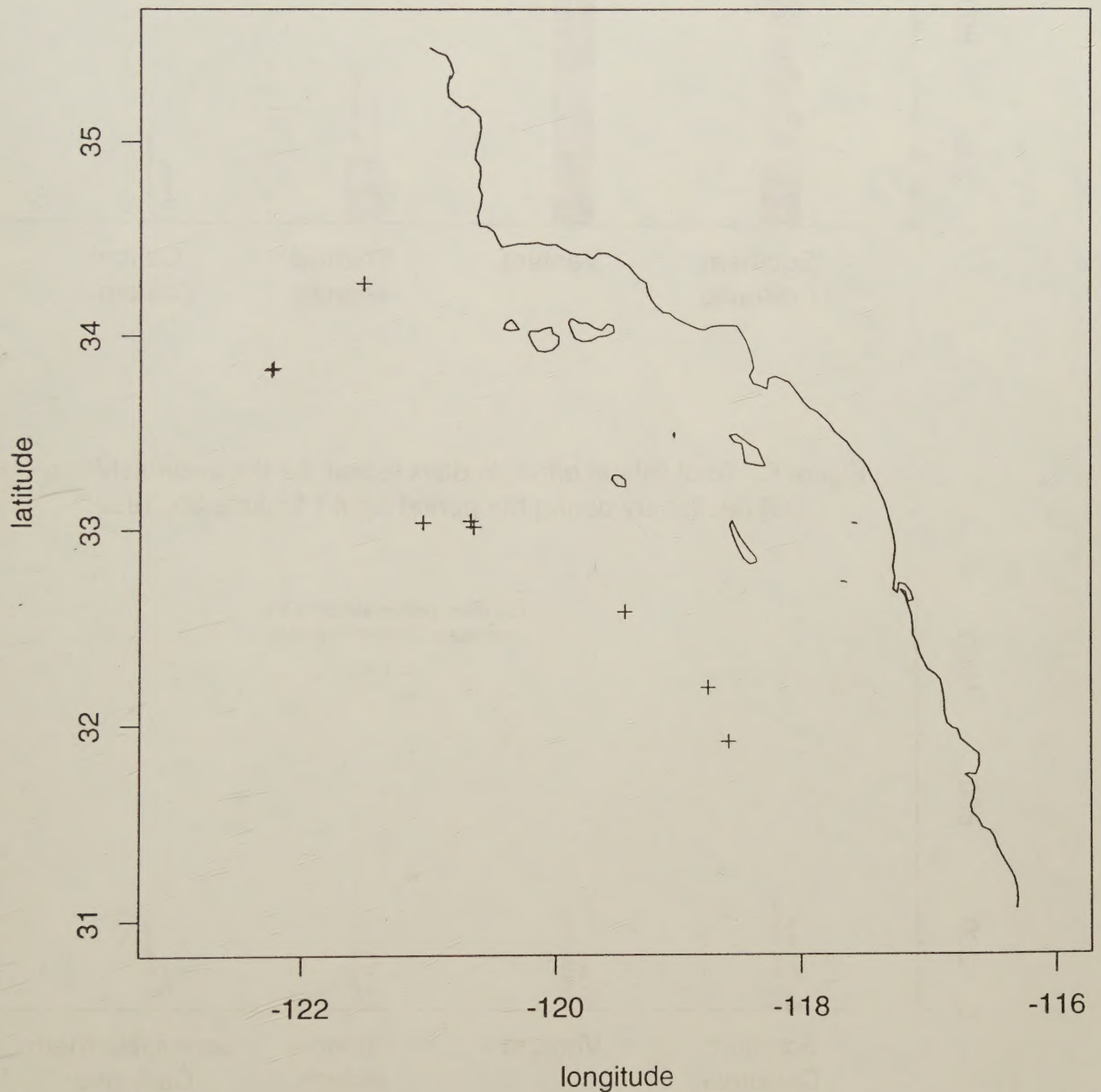


Figure 5. Total fishing effort, in days fished, for the halibut/angel shark set-net fishery during the period April 1 to June 30, 1992.

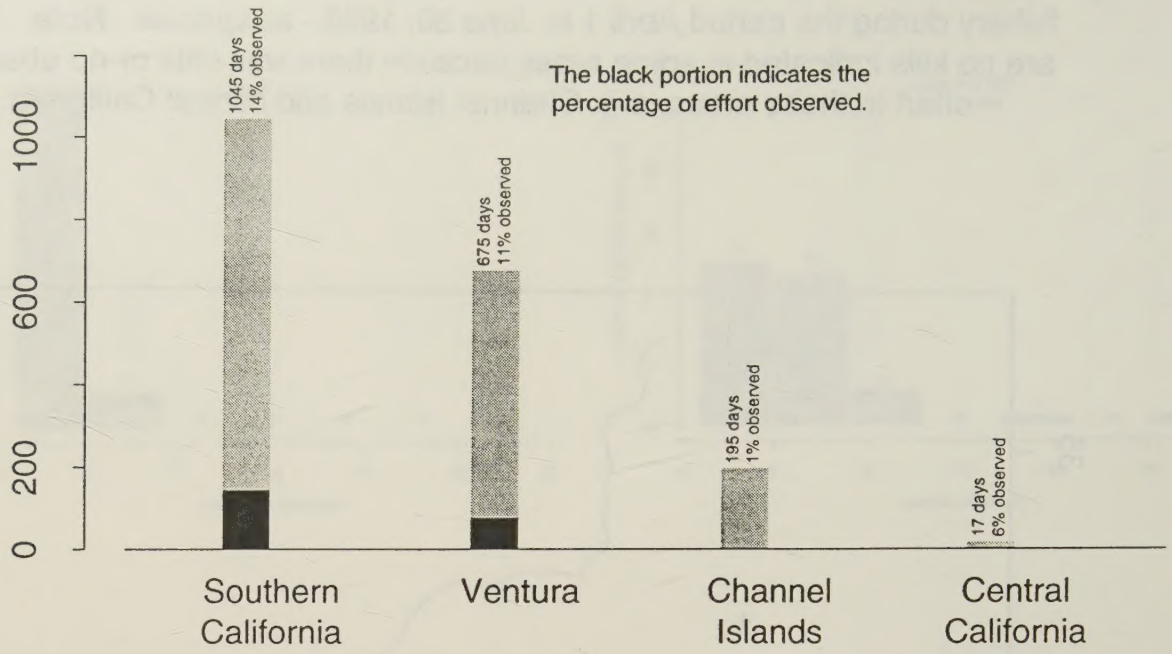


Figure 6. Total fishing effort, in days fished, for the swordfish/shark drift-net fishery during the period April 1 to June 30, 1992.